Project Title:	Feasibility of Delivering High-rise Low or Zero Carbon Buildings in Hong Kong
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Objective

This project aims to examine the feasibility of delivering high-rise Low or Zero Carbon Buildings (L/ZCBs) in Hong Kong, and to develop scenario-based design solutions to enable the delivery of high-rise buildings towards zero carbon emission in the long term.

Background

L/ZCB is regarded as the most innovative model of sustainable development in the built environment. Many governments have adopted the L/ZCB model as an important strategy for addressing climate change, achieving a low carbon economy and improving the quality of human life. In the recent Paris Agreement, low greenhouse gas emissions development has been set as a fundamental climate change strategy. These goals, although varied in the context of their policy and implementation, are creating unprecedented challenges in both research and practice to identify and implement feasible decisions on delivering L/ZCBs.

In Hong Kong, buildings consume 92% of electricity and contribute 60% of the city's carbon emissions, which are much higher than the worldwide averages. The HKSAR government has pledged to achieve a reduction in carbon intensity of at least 50% to 60% on the 2005 baseline by 2020. The Hong Kong Green Building Council proposed the 'HK3030' vision, based on demand side management, to reduce the absolute electricity consumption in buildings by 30% by 2030 as compared to 2005 levels. The Chief Executive of the HKSAR Government has committed in its 2013 Policy Address to promote green building. These contextual factors together suggest an unprecedented opportunity for L/ZCB, as a cutting-edge model of green building, to help drive the transition of the Hong Kong built environment towards low carbon and sustainable development.

Data and Methodology

The L/ZCB scenarios cover two types of high-rise buildings in Hong Kong, public residential and private office. The design solutions draw on representative building shape, orientation, number of storeys, design specifications, construction methods, energy fuel mix and solutions in order to maximize the potential to take-up of L/ZCB practice in the Hong Kong construction industry. The development and verification of scenario-based design solutions and feasibility examination were conducted using two real-life cases of building projects. Parametric simulation and sensitivity analyses coupled with engagement of professionals substantiated the quantification of the impact of wide-ranging design measures on the buildings' energy consumption.

Method for Studying Public Residential Buildings

A 40-storey public housing block located in Kai Tak area was selected as the reference building for the examination of delivering high-rise public residential L/ZCBs. A detailed energy model with precise building configuration was developed using energy simulation software DesignBuilder. The final energy modelling inputs were determined through careful calibration using the measured energy use data. By the building envelope information and equipment specifications, a Base Case Scenario was developed. Sensitivity analyses were then conducted using the parametric simulation tool jEPlus for developing the Quick-Win Scenario.

Method for Studying Private Office Buildings

A 26-storey private office building achieved BEAM Plus Gold level with mixed-use functions located in Kowloon was selected as the reference building for the examination of delivering high-rise private office L/ZCBs. A detailed energy model with precise building geometry, space division, façade configuration and system specification was built using the software DesignBuilder. Possible energy saving design measures were first identified through a literature review. Then, using the Base Case energy model, sensitivity analyses were conducted using jEPlus to quantify the impact of these measures on the building's energy consumption. By integrating suitable energy saving design strategies, the Quick-Win Scenario was developed.

For both methods, a desk study was conducted to explore possible social and advanced technical solutions, and this led to the development of the Optimization Scenario to further reduce the building's energy consumption and carbon emissions. Moreover, the Decarburization Scenario and Emerging Renewable Scenario were explored for the further strategic reduction of building energy use and carbon emissions.

Results and Findings

Public Residential Buildings

The energy use intensity (EUI) is 106.6 kWh/(m^2-yr) and the carbon emission intensity (CEI) is 55.51 kg/(m^2-yr). At first glance, this EUI greatly challenges the feasibility of achieving net zero energy or carbon. Due to the hot-and-humid and high-rise features of buildings in Hong Kong, the EUI is unavoidably much higher than that of low to medium-rise buildings in temperate climates. Also, cooking gas and appliances are included in the EUI calculations, which is different from many other countries. These findings explain the perceived infeasibility of and apparent great challenge to delivering net zero carbon.

The Quick-Win Scenario is substantially less energy use and carbon emission intensive. The EUI is reduced to 91.5 kWh/(m^2-yr), and the CEI is reduced to 39.71 kg/(m^2-yr). The combination of cooking gas and appliances account for over half of the building energy use (50.35%). This technically optimized case considers the use of PV and wind turbine, which together help to further reduce the net EUI by 11% to 79.8 kWh/(m^2-yr), yielding a total EUI and CEI reduction of 25% and 28.5% over the Base Case, respectively.

The Optimization Scenario is significantly less energy use and carbon emissions intensive. The EUI is further reduced to 76.5 kWh/(m^2-yr), and the CEI is further reduced to 23.12kg/(m^2-yr). The combination of cooking gas and appliances account for over half of the building energy use (52.59%). This ideal case considers the use of more advanced PV and wind turbines, which together help to further reduce the net EUI by 30% to 53.88kWh/(m^2-yr), yielding a total EUI and CEI reduction of 49% and 58.3% over the Base Case, respectively.

According to the above-summarized findings, it is concluded that the maximum potential of achieving technically feasible reductions is 49% EUI and 58.3% CEI. This represents very low energy and low carbon high-rise residential buildings, particularly for a hot-and-humid climate. However, it is also concluded that it is technically not feasible to achieve net-zero carbon or net-zero energy for high-rise public residential buildings in Hong Kong given the current carbon-intensive energy supply and the renewable energy and carbon reduction technologies presently available in the market.

Private Office Buildings

The EUI is 282.4kWh/(m^2-yr) covering, and the CEI is 197.7 kg/(m^2-yr). Similar to the public residential buildings, these findings explain the perceived infeasibility of and apparent great challenge to delivering net zero carbon office buildings in Hong Kong.

The Quick-Win Scenario is substantially less energy use and carbon emission intensive than the Base Case. The EUI is reduced to 188.86 kWh/(m^2-yr), and the CEI is reduced to 124.96 kg/(m^2-yr). This technically optimized case considers the use of PV and wind turbines, which together help to further reduce the net EUI by 7.1% to 175.5 kWh/(m^2-yr), yielding a total EUI and CEI reduction of 38% and 38%, respectively, over the Base Case.

The Optimization Scenario is significantly less energy use and carbon emission intensive. The EUI is further reduced to 149.52 kWh/(m^2-yr), and the CEI is further reduced to 84.14 kg/(m^2-yr). This ideal case also considers the use of PV and wind turbines, which together help to further reduce the net EUI by 19.65% to 120.2 kWh/(m^2-yr), yielding a total EUI and CEI reduction of 57% and 57%, respectively, over the Base Case.

According to the above-summarized findings it is concluded that the maximum potential of achieving technically feasible reductions is 57% EUI and 57% CEI. Similar to the public residential buildings, it is concluded that it is technically not feasible to achieve net-zero carbon or net-zero energy for high-rise private office buildings in Hong Kong given the current carbon-intensive energy supply and the renewable energy and carbon reduction technologies presently available in the market.

Recommendations

To achieve high-rise net zero carbon in the long term, more efficient or emerging renewable energy technologies and/or decarburization technologies must be explored and adopted, of which two strategic scenarios are developed:

- Emerging Renewable Scenario, which is based on the Optimization Scenario but further takes into account emerging renewable energy technologies such as combined cooling heating and power (CCHP) and fuel cells (FC), that together may further reduce the net energy use of the building towards zero or negative;
- Decarburization Scenario, which is also based on the Optimization Scenario but in addition takes into account measures such as decarbonized electricity generation, changing the fuel mix, carbon capture & storage (CCS), and planting trees, that together may further reduce the net carbon emissions of the building towards zero or negative.

It is more realistic to integrate some of the technologies and measures proposed for the two strategic scenarios in order to more effectively achieve energy use and carbon emission reductions.

Way Forward

- The industry should raise awareness of these scenarios and design solutions in new building planning and design. The industry may take as a reference point these scenarios and design solutions in future revisions of the BEAM Plus scheme.
- The industry should also establish a performance database or portal, and nurture a sharing culture, as sharing performance data and good practices, as well as lessons learned, are critical to understanding and exploring emerging renewable energy technologies.

- Universities should continue exploring systems theory within the context of high-rise L/ZCB. Universities and institutions should integrate L/ZCB into their curricula and programmes, as education is fundamental to shaping user behaviours, changing the design practices of professionals, raising awareness and ensuring that client investment decisions are properly founded.
- The government should implement its proposed fuel mix and consider adopting a L/ZCB policy, as decarbonizing electricity generation and changing the fuel mix for energy supply are crucial to achieving net zero carbon in the long term.
- Government, industry and university stakeholder groups should work together to further explore the two strategic scenarios, namely, the Emerging Renewable and the Decarburization Scenarios, together with their underlying technologies and solutions for addressing the socio-technical aspects of their feasibility.